

RESIDENTIAL ACM APPENDIX RF

Appendix RF – HVAC Sizing

RF1. Purpose and Scope

ACM RF-2005 is a procedure for calculating the cooling load in low-rise residential buildings (Section RF2) and for determining the maximum cooling capacity for credit in ACM calculations (Section RF3). Section RF4 has a procedure for determining compliance for oversized equipment by showing that the peak power is equal to or less than equipment that minimally meet the requirements of this section.

RF2. Procedure for Calculating Design Cooling Capacity

The following rules apply when calculating the design cooling:

RF2.1 Methodology

The methodologies, computer programs, inputs, and assumptions approved by the commission shall be used.

RF2.2 Cooling Loads

Except as specified in this section, calculations will be done in accordance with the method described in Chapter 28, Residential Cooling and Heating Load Calculations, 2001 ASHRAE Fundamentals Handbook. Interpolation shall be used with tables in Chapter 28. The methods in Chapter 29 may not be used under this procedure.

RF2.3 Indoor Design Conditions

The indoor cooling design temperature shall be 75°F. An indoor design temperature swing of 3°F shall be used.

RF2.4 Outdoor Design Conditions

Outdoor design conditions shall be selected from the 1.0 Percent Cooling Dry Bulb and Mean Coincident Wet Bulb values in Joint Appendix II REF

RF2.5 Block Loads

The design cooling capacity used for calculating the maximum allowable cooling capacity is based on the block (peak) load either for

1. The whole building; or
2. For each zone within a building that is served by its own cooling system; or
3. For each dwelling unit within a building that is served by its own cooling system.

Room-by-room loads are not allowed for calculating the design cooling capacity.

RF2.6 Table Selection

Tables 2 (cooling load temperature differences) and 4 (glass load factors) shall be used for:

1. Buildings with more than one dwelling unit using whole building block loads; or

2. Buildings or zones with either east or west exposed walls but not both east and west exposed walls. Otherwise, Tables 1 (cooling load temperature differences) and 3 (glass load factors) shall be used.

Note: The table numbers refer to the ASHRAE Fundamentals 2001.

RF2.7 U-factors

U-factors for all opaque surfaces and fenestration products shall be consistent with the methods described in Section 4.2 and Section 4.3 of the Residential ACM Manual. The effects of radiant barriers or cool roofs shall be included if these features are in the proposed building.

RF2.8 Solar Heat Gain Coefficients

Solar heat gain coefficients (SHGC) shall be equal to the $SHGC_{closed}$ values described in Section 4.3.4 of the Residential ACM Manual.

RF2.9 Glass Load Factors

Glass load factors (GLFs) shall be calculated using the equation in the footnotes of Tables 3 and 4 in Chapter 28 using the columns for "Regular Double Glass" and the rows for "Draperies, venetian blinds, etc". The table values used in the equation shall be $U_i = 0.55$ and $SC_i = 0.45$. The shading coefficient for the alternate value shall be $SC_a = SHGC \times 0.87$ where the SHGC value is described above. The GLF values shall also be adjusted for latitude as described in the footnotes.

Note: The table numbers refer to the ASHRAE Fundamentals 2001.

RF2.10 Infiltration

The air flow (CFM) due to infiltration and mechanical ventilation shall be calculated with the effective leakage area method as documented in Section 4.5.1 of the Residential ACM Manual using the outdoor design temperature minus the indoor design temperature as the temperature difference and a 7.5 mph wind speed.

RF2.11 Internal Gain

Occupancy shall be assumed to be two persons for the first bedroom and one person for each additional bedroom per dwelling unit. Each person shall be assigned a sensible heat gain of 230 Btu/hr. Appliance loads shall be 1200 Btu/hr for multifamily buildings with common floors and ceilings. Otherwise the appliance load is 1600 Btu/hr.

RF2.12 Cooling Duct Efficiency

The cooling duct efficiency shall be calculated using the seasonal approach as documented in ACM Section 4.8.8 ~~RB-2005~~.

RF2.13 Latent Factor.

The latent factor shall be 1.0.

RF2.14 Total Cooling Load

The total cooling load is calculated in accordance with Table 9 of Chapter 28 of ASHRAE Handbook, Fundamentals Volume, 2001, using the values specified in this section.

RF2.15 Design Cooling Load

The design cooling load is equal to the total cooling load divided by the cooling duct efficiency.

RF2.16 Design Cooling Capacity

The design cooling capacity calculation adjusts the sensible design cooling load to estimate the rated cooling capacity needed as follows:

Equation RF-1 _____

$$\text{Design Cooling Capacity (Btu/hr)} = \frac{\text{Design Cooling Load (Btu/hr)}}{(0.88 + (0.002286 \times (\text{Outdoor Cooling Design Temperature } (^{\circ}\text{F}) - 95)))}$$

$$\text{Design Cooling Capacity (Btu/hr)} = \text{Design Cooling Load (Btu/hr)} \times (0.8192 + 0.0038 \times \text{Outdoor Cooling Design Temperature } (^{\circ}\text{F}))$$

RF3. Procedure for Calculating Maximum Cooling Capacity for ACM Credit

The following rules apply when calculating the maximum cooling capacity for ACM credit:

RF3.1 Design Cooling Capacity

The design cooling capacity shall be calculated in accordance with the procedure described in RF2.

RF3.2 Maximum Cooling Capacity for ACM Credit

For buildings with a single cooling system or for buildings where the design cooling capacity has been calculated separately for each cooling system, the maximum cooling capacity for ACM credit for each cooling system shall be:

Table RF-1 – Maximum Cooling Capacity for ACM Credit

Design Cooling Capacity (Btu/hr)	Maximum Cooling Capacity for ACM Credit (Btu/hr)
< 48000	Design Cooling Capacity + 6000
48000 - 60000	Design Cooling Capacity + 12000
>60000	Design Cooling Capacity + 30000

For buildings with more than one cooling system where the design cooling capacity has been calculated for the entire building, the maximum cooling capacity for ACM credit for the entire building shall be:

Equation RF-2 _____

$$\text{Maximum Cooling Capacity for ACM Credit (Btu/hr)} = \text{Design Cooling Capacity (Btu/hr)} + (6000 \text{ (Btu/hr)} \times \text{Number of Cooling Systems})$$

RF3.3 Multiple Orientations

For buildings demonstrating compliance using the multiple orientation alternative of Section 151(c), the maximum cooling capacity for ACM credit is the highest, considering north, northeast, east, southeast, south, southwest, west and northwest of the four cardinal orientations. For buildings with more than one cooling system, the orientation used for determining the maximum cooling capacity for ACM credit shall be permitted to be different for each zone.

RF4. Procedure for Determining Electrical Input Exception for Maximum Cooling Capacity for ACM Credit

The installed cooling capacity shall be permitted to exceed the maximum cooling capacity for ACM credit if the electrical input of the oversized cooling system is less than or equal to the electrical input of a standard cooling system using the following rules:

RF4.1 Design Cooling Capacity

The design cooling capacity shall be calculated in accordance with the procedure described in RF2.

RF4.2 Standard Total Electrical Input

The standard electrical input is calculated as follows:

$$\text{Equation RF-3} \quad \text{Standard Total Electrical Input (W)} = \frac{0.1170.1048 \text{ (W/Btu/hr)} \times \text{Design Cooling Capacity (Btu/hr)}}{1}$$

RF4.3 Proposed Electrical Input

The proposed electrical input (W) for the installed cooling system is calculated as follows:

$$\text{Equation RF-4} \quad \text{Proposed Compressor Electrical Input (W)} = \frac{\text{Electrical Input (W)} - (.0122 \times \text{Design Cooling Capacity (Btu/hr)})}{1}$$

Where "Electrical Input" is as published in the Directories of Certified Appliances maintained by the California Energy Commission in accordance with the requirements of the Appliance Standards.

The proposed electrical input (W) for the installed cooling system is published as the "Electrical Input" in the Directories of Certified Appliances maintained by the California Energy Commission in accordance with the requirements of the Appliance Standards.

RF4.4 Proposed Fan Power

The proposed fan power (W) of the installed cooling system is equal to either:

1. $0.017 \text{ (W/Btu/hr)} \times \text{Design Cooling Capacity (Btu/hr)}$; or
2. The measured fan power (W) where the measured fan power is determined using the procedure described in ACM RE-2005 of the *Residential ACM Manual*.

RF4.5 Proposed Total Electrical Input

The proposed electrical input is equal to:

$$\text{Equation RF-5} \quad \text{Proposed Total Electrical Input (W)} = \frac{\text{Proposed Electrical Input (W)} + \text{Proposed Fan Power (W)}}{1}$$

For buildings with more than one cooling system, the proposed total electrical power shall be the sum of the values for each system. If the proposed total electrical input is less than or equal to the standard total electrical input, then the installed cooling capacity may exceed the allowable cooling capacity for ACM credit.

~~APPENDIX F~~

Appendix F

Standard Procedure for Determining the Seasonal Energy Efficiencies of Residential Air Distribution Systems

1.0 Introduction

This appendix describes the measurement and calculation methods for determining air distribution system efficiency.

2.0 Definitions

aerosol sealant closure system: A method of sealing leaks by blowing aerosolized sealant particles into the duct system and which must include minute-by-minute documentation of the sealing process.

floor area: The floor area of enclosed conditioned space on all floors of a building, as measured at the floor level of the exterior surfaces enclosing the conditioned space.

delivery effectiveness: The ratio of the thermal energy delivered to the conditioned space and the thermal energy entering the distribution system at the equipment heat exchanger.

distribution system efficiency: The ratio of the thermal energy consumed by the equipment with the distribution system to the energy consumed if the distribution system had no losses or impact on the equipment or building loads.

equipment efficiency: The ratio between the thermal energy entering the distribution system at the equipment heat exchanger and the energy being consumed by the equipment.

equipment factor: F_{equip} is the ratio of the equipment efficiency including the effects of the distribution system to the equipment efficiency of the equipment in isolation.

fan flowmeter device: A device used to measure air flow rates under a range of test pressure differences.

flowhood: A device used to capture and measure the airflow at a register.

load factor: F_{load} is the ratio of the building energy load without including distribution effects to the load including distribution system effects.

pressure pan: a device used to seal individual forced air system registers and to measure the static pressure from the register.

radiant barrier: a surface of low emissivity (less than 0.05) placed inside an attic or roof space to reduce radiant heat transfer.

recovery factor: F_{recovery} is the fraction of energy lost from the distribution system that enters the conditioned space.

thermal regain: The fraction of delivery system losses that are returned to the building.

3.0 Nomenclature

α_r = duct leakage factor (1 return leakage) for return ducts

α_s = duct leakage factor (1 supply leakage) for supply ducts

A_{floor} = conditioned floor area of building, ft²

A_{return} = surface area of return duct outside conditioned space, ft²

A_{rattic} = return duct area in attic, ft²

$A_{r, \text{basement}}$ = return duct area in basement, ft^2	T_{seasonal} = outdoor air seasonal temperature, $^{\circ}\text{F}$
$A_{r, \text{crawl}}$ = return duct area in crawlspace, ft^2	T_{sp} = supply plenum air temperature, $^{\circ}\text{F}$
$A_{r, \text{gar}}$ = return duct area inside garage, ft^2	ΔT_e = temperature rise across heat exchanger, $^{\circ}\text{F}$
$A_{r, \text{out}}$ = surface area of supply duct outside conditioned space, ft^2	ΔT_r = temperature difference between indoors and the ambient for the return, $^{\circ}\text{F}$
$A_{r, \text{attic}}$ = supply duct area in attic, ft^2	ΔT_s = temperature difference between indoors and the ambient for the supply, $^{\circ}\text{F}$
$A_{r, \text{basement}}$ = supply duct area in basement, ft^2	$\eta_{\text{dist, seasonal}}$ = seasonal distribution system efficiency
$A_{r, \text{crawl}}$ = supply duct area in crawlspace, ft^2	
$A_{r, \text{gar}}$ = supply duct area inside garage, ft^2	
$A_{r, \text{in}}$ = supply duct area inside conditioned space, ft^2	
B_r = conduction fraction for return	
B_s = conduction fraction for supply	
DE = delivery effectiveness	
DE _{design} = design delivery effectiveness	
DE _{seasonal} = seasonal delivery effectiveness	
E_{equip} = rate of energy exchanged between equipment and delivery system, Btu/hour	
$F_{\text{cyclic loss}}$ = cyclic loss factor	
F_{equip} = load factor for equipment	
F_{flow} = load factor for fan flow effect on equipment efficiency	
F_{leak} = fraction of system fan flow that leaks out of supply or return ducts	
F_{load} = load factor for delivery system	
F_{recov} = thermal loss recovery factor	
F_{regain} = thermal regain factor	
K_r = return duct surface area coefficient	
K_s = supply duct surface area coefficient	
N_{story} = number of stories of the building	
P_{sp} = pressure difference between supply plenum and conditioned space [Pa]	
P_{test} = test pressure for duct leakage [Pa]	
Q_s = Flow through air handler fan at operating conditions, cfm	
$Q_{\text{total, 25}}$ = total duct leakage at 25 Pascal, cfm	
R_r = thermal resistance of return duct, $\text{h ft}^2 \text{F/Btu}$	
R_s = thermal resistance of supply duct, $\text{h ft}^2 \text{F/Btu}$	
$T_{\text{amb, r}}$ = ambient temperature for return, $^{\circ}\text{F}$	
$T_{\text{amb, s}}$ = ambient temperature for supply, $^{\circ}\text{F}$	
T_{attic} = attic air temperature, $^{\circ}\text{F}$	
T_{basement} = return duct temperature in basement, $^{\circ}\text{F}$	
T_{crawl} = return duct temperature in crawlspace, $^{\circ}\text{F}$	
T_{design} = outdoor air design temperature, $^{\circ}\text{F}$	
T_{ground} = ground temperature, $^{\circ}\text{F}$	
T_{gar} = temperature of garage air, $^{\circ}\text{F}$	
T_{in} = temperature of indoor air, $^{\circ}\text{F}$	
T_{sp} = return plenum air temperature, $^{\circ}\text{F}$	

4.0 Air Distribution Diagnostic Measurement and Default Assumptions

4.1 Instrumentation Specifications

The instrumentation for the air distribution diagnostic measurements shall conform to the following specifications:

4.1.1 Pressure Measurements

All pressure measurements shall be measured with measurement systems (i.e. sensor plus data acquisition system) having an accuracy of ± 0.2 Pa. All pressure measurements within the duct system shall be made with static pressure probes.

4.1.2 Fan Flow Measurements

All measurements of distribution fan flows shall be made with measurement systems (i.e. sensor plus data acquisition system) having an accuracy of $\pm 5\%$ reading or ± 5 cfm whichever is greater.

4.1.3 Duct Leakage Measurements

The measurement of air flows during duct leakage testing shall have an accuracy of $\pm 3\%$ of measured flow using digital gauges.

All instrumentation used for fan flow and duct leakage diagnostic measurements shall be calibrated according to the manufacturer's calibration procedure to conform to the above accuracy requirement. All testers performing diagnostic tests shall obtain evidence from the manufacturer that the equipment meets the accuracy specifications. The evidence shall include equipment model, serial number, the name and signature of the person of the test laboratory verifying the accuracy, and the instrument accuracy. All diagnostic testing equipment is subject to re-calibration when the period of the manufacturer's guaranteed accuracy expires.

4.2 Apparatus

4.2.1 System Fan Flows

HVAC system fan flow shall be measured using one of the following methods.

4.2.1.1 Plenum pressure matching measurement

The apparatus for measuring the system fan flow shall consist of a duct pressurization and flow measurement device (subsequently referred to as a fan flowmeter [see section 4.3.7.2.2.]) meeting the specifications in 4.1.3, a static pressure transducer meeting the specifications in Section 4.1.1, and an air barrier between the return duct system and the air handler inlet. The measuring device shall be attached at the air handler blower

~~compartment door. All registers shall be in their normal operating condition. The static pressure probe shall be fixed to the supply plenum so that it is not moved during this test.~~

4.2.1.2 Flow hood measurement

~~A flow hood meeting the specifications in section 4.1.2, can be used to verify the fan flow at the return register(s) after the completion of a rough-in duct leakage measurement. All registers shall be in their normal operating position. Measurement(s) shall be taken at the return grill(s).~~

4.2.2 Duct Leakage

~~The apparatus for fan pressurization duct leakage measurements shall consist of a duct pressurization and flow measurement device meeting the specifications in Section 4.1.3.~~

4.3 Procedure

~~The following sections identify input values for building and HVAC system (including ducts) using either default or diagnostic information.~~

4.3.1 Building Information

~~The calculation procedure for determining air distribution efficiencies requires the following building information:~~

- ~~1. climate zone for the building,~~
- ~~2. conditioned floor area,~~
- ~~3. number of stories,~~
- ~~4. supply duct location and~~
- ~~5. floor type.~~

4.3.1.1 Default Input

~~Using default values rather than diagnostic procedures produce relatively low air distribution system efficiencies. Default values shall be obtained from following sections: —~~

- ~~1. the location of the duct system in Section 4.3.4,~~
- ~~2. the surface area and insulation level of the ducts in Sections 4.3.3, 4.3.4 and 4.3.6,~~
- ~~— 3. the system fan flow in Section 4.3.7, and~~
- ~~— 4. the leakage of the duct system in Section 4.3.8.~~

4.3.2 Diagnostic Input

~~Diagnostic inputs are used for the calculation of improved duct efficiency. The diagnostics include observation of various duct characteristics and measurement of duct leakage and system fan flows as described in Sections 4.3.5 through 4.3.8. These observations and measurements replace those assumed as default values.~~

The diagnostic procedures include

- ~~measure supply duct surface area as described in Section 4.3.3.2.?~~
- ~~measure total duct system leakage as described in Section 4.3.8.~~
- ~~measure system fan flow or observe the presence of a thermostatic expansion valve for claiming ACCA manual D design credit as described in Section 4.3.7.~~
- ~~Observe the insulation level for the supply (R_s) and return (R_r) ducts outside the conditioned space as described in Section 4.3.6.~~
- ~~Observe the presence of radiant barriers.~~

4.3.3 Duct Surface Area

The supply-side and return-side duct surface areas shall be calculated separately. If the supply or return duct is located in more than one zone, the area of that duct in each zone shall be calculated separately. The duct surface area shall be determined using the following methods.

4.3.3.1 Default Duct Surface Area

4.3.3.1.1 Duct Surface Area for More Than 12 feet of Duct Outside Conditioned Space

The default duct surface area for supply and return shall be calculated as follows:

For supplies:

$$A_{s,\text{total}} = 0.27 A_{\text{floor}} \quad (4.1)$$

For returns:

$$A_{r,\text{total}} = K_r A_{\text{floor}} \quad (4.2)$$

Where K_r (return duct surface area coefficient) shall be 0.05 for one story building and 0.1 for two or more stories.

4.3.3.1.1 Duct Surface Area for Less Than 12 feet of Duct Outside Conditioned Space

For HVAC systems with air handlers located outside the conditioned space but with less than 12 feet of duct located outside the conditioned space including air handler and plenum, the duct surface area outside the conditioned space shall be calculated as follows:

$$A_{s,\text{out}} = 0.027 A_{\text{floor}} \quad (4.3)$$

Where $A_{s,out}$ is substituted for $A_{s,attic}$, $A_{s,crawl}$, or $A_{s,base}$ depending on the location of the ducts.

4.3.3.2 Diagnostic Duct Surface Area

A well designed duct system can reduce the length of the supply duct. Smaller duct surface area will result in reduced duct conduction losses. Duct surface area shall be calculated from measured duct lengths and nominal outside diameters (for round ducts) or outside perimeters (for rectangular ducts) of each duct run in the building. Improved conduction losses can be claimed for reduced supply duct surface area only (it does not apply to the return duct). Supply plenum surface area shall be included in the supply duct surface area. Diagnostic duct surface area requires measuring duct surface areas separately for each location outside conditioned space ($A_{s,attic}$, $A_{s,crawl}$, or $A_{s,base}$) and the system fan flow to ensure that there is sufficient air flow to deliver the designed heating and cooling loads.

4.3.4 Duct Location

Duct location determines the external temperature for duct conduction losses, the temperature for return leaks, and the thermal regain of duct losses. Default duct surface areas by locations of the supply duct shall be obtained from Table 4.1. The default duct surface area for crawlspace and basement applies only to buildings with all supply ducts installed in the crawlspace or basement. If the supply duct is installed in locations other than crawlspace or basement, the default supply duct location shall be "Other".

If ducts are installed in multiple locations, air distribution efficiency shall be calculated for each duct location. Total air distribution efficiency for the house shall be the weighted average based on the floor area served by each duct system.

Table 4.1 Default Assumptions for Duct Locations

Supply or Return Duct Location	Supply Duct Surface Area		Return Duct Surface Area	
	One story	Two or more story	One story	Two or more story
Attic	100% attic	65% attic 35% conditioned space	100% attic	100% attic
Crawlspace	100% crawlspace	65% crawlspace 35% conditioned space	100% attic	100% attic
Basement	100% Basement	65% basement 35% conditioned space	100% Basement	100% Basement
Other	100% attic	65% attic 35% conditioned space	100% attic	100% attic

4.3.5 Climate and Duct Ambient Conditions for Ducts Outside Conditioned Space

Duct ambient temperature for both heating and cooling at different duct locations shall be obtained from Table 4.2. Indoor dry-bulb (T_{in}) temperature for cooling is 78°F. The indoor dry-bulb temperature for heating is 70°F. Reduction of attic temperature and the reduction in solar radiation effect due to radiant barriers shall only be

applied to cooling calculations. The procedures for the installation of radiant barriers shall be as described in ACM Section 4.23. Attic temperatures for houses with radiant barriers shall be obtained from Table 4.2.

Table 4.2 Default Assumptions for Duct Ambient Temperature

Climate zone	Duct Ambient Temperature for Heating, $T_{\text{heat,amb}}$			Duct Ambient Temperature for Cooling, $T_{\text{cool,amb}}$				
	Attic	Crawlspace	Basement	Attic	Attic w/ radiant barrier (supply)	Attic w/ radiant barrier (return)	Crawlspace	Basement
1	52.0	52.2	48.9	60.0	65.4	61.2	54.0	49.1
2	48.0	48.7	56.5	87.0	84.3	84.2	78.0	64.5
3	55.0	54.9	58.3	80.0	79.4	78.2	71.8	62.8
4	53.0	53.1	56.6	79.0	78.7	77.4	70.9	61.4
5	49.0	49.6	52.3	74.0	75.2	73.1	66.4	56.8
6	57.0	56.7	59.9	81.0	80.1	79.1	72.7	64.1
7	62.0	61.1	60.4	74.0	75.2	73.1	66.4	61.6
8	58.0	57.6	60.1	80.0	79.4	78.2	71.8	63.9
9	53.0	53.1	59.6	87.0	84.3	84.2	78.0	66.4
10	53.0	53.1	61.1	91.0	87.1	87.6	81.6	68.9
11	48.0	48.7	59.5	95.0	89.9	91.0	85.1	69.5
12	50.0	50.4	59.3	91.0	87.1	87.6	81.6	67.8
13	48.0	48.7	58.4	92.0	87.8	88.4	82.4	67.6
14	39.0	40.7	55.4	99.0	92.7	94.4	88.7	68.6
15	50.0	50.4	63.4	102.	94.8	96.9	91.3	74.6
16	32.0	34.4	43.9	80.0	79.4	78.2	71.8	54.1

4.3.6 Duct Wall Thermal Resistance

4.3.6.1 Default Duct Insulation R value

Default duct wall thermal resistance is R4.2. An air film resistance of 0.7 [$\text{h ft}^2 \cdot ^\circ\text{F}/\text{BTU}$] shall be added to the duct insulation R value to account for external and internal film resistance.

4.3.6.2 Diagnostic Duct Wall Thermal Resistance

Duct wall thermal resistance shall be determined from the manufacturer's specification observed during diagnostic inspection. If ducts with multiple R values are installed, the lowest duct R value shall be used. If a duct with a higher R value than 4.2 is installed, the R value shall be clearly stated on the building plan and a visual inspection of the ducts must be performed to verify the insulation values. In case the space on top of

~~the duct boot is limited and can not be inspected, the insulation R value within two feet of the boot to which the duct is connected may be excluded from the determination of the overall system R value.~~

4.3.7 System Fan Flow

4.3.7.1 Default Fan Flow

~~The default cooling fan flow with an air conditioner and for heating with a heat pump for climate zones 8 through 15 shall be calculated as follows:~~

$$Q_e = 0.70 A_{\text{floor}} \quad (4.4)$$

~~The default cooling fan flow with an air conditioner and for heating with a heat pump for climate zones 1 through 7 and 16 and default heating fan flow for forced air furnaces for all climate zones shall be calculated as follows:~~

$$Q_e = 0.50 A_{\text{floor}} \quad (4.5)$$

4.3.7.2 Diagnostic Fan Flow

~~To obtain duct efficiency credit for duct systems designed according to ACCA Manual D, a diagnostic fan flow measurement must be performed or the installation of a thermostatic expansion valve must be verified. The access panel on the cooling coil shall be removable for the verification of a thermostatic expansion valve. For ACCA Manual D designed duct system, engineering calculations and the building plan for duct sizing and layout shall also be prepared. The diagnostic fan flow measurement shall be measured using one of the following methods:~~

4.3.7.2.1 Diagnostic Fan Flow Using Flow Hood:

~~To measure the system return fan flow, all registers shall be fully open, and the air filter shall be installed. Turn on the system fan and measure the fan flow at the return grille(s) with a calibrated flow hood to determine the total system return fan flow. The system fan flow (Q_e) shall be the sum of the measured return flows.~~

4.3.7.2.2 Diagnostic Fan Flow Using Plenum Pressure Matching:

~~The fan flow measurement shall be performed using the following procedures:~~

- ~~1. With the system fan on (in heating mode with burners on for heating, or in cooling mode with compressor on), measure the pressure difference (in pascal) between the supply plenum and the conditioned space (ΔP_{sp}). P_{sp} is the target pressure to be maintained during the fan flow tests. If there is no access to the supply plenum, then place the pressure probe in the nearest supply duct. Adjust the probe to achieve the highest pressure and then firmly attach the probe (e.g., with duct tape) to ensure that it does not move during the fan flow test.~~

2. ~~Block the return duct from the plenum upstream of the air handler fan and the fan flowmeter. Filters are often located in an ideal location for this blockage.~~
3. ~~Attach the fan flowmeter device to the duct system at the air handler. For many air handlers, there will be a removable section that allows access to the fan that is suitable for this purpose. Assure that there is no significant leakage between the fan flowmeter and the system fan.~~
4. ~~If the fan flowmeter is connected to the air handler outside the conditioned space, then the door or access panel between the conditioned space and the air handler location shall be opened.~~
5. ~~Turn on the system fan and the fan flowmeter, adjust the fan flowmeter until the pressure between supply plenum and conditioned space matches P_{sp} .~~
6. ~~Record the flow through the flowmeter (Q_o , cfm) - this is the diagnostic fan flow.~~

~~In some systems, typical system fan and fan flowmeter combinations may not be able to produce enough flow to reach P_{sp} . In this case record the maximum flow (Q_{max} , cfm) and pressure (P_{max}) between the supply plenum and the conditioned space. The following equation shall be used to correct measured system flow and pressure (Q_{max} and P_{max}) to operating condition (Q_o) at operating pressure (P_{sp}).~~

$$Q_e = Q_{max} \left(\frac{P_{sp}}{P_{max}} \right)^{\frac{1}{2}} \quad (4.6)$$

4.3.8 Duct Leakage

4.3.8.1 Duct Leakage Factor for Delivery Effectiveness Calculations

Default duct leakage factors shall be obtained from Table 4.3, using the "not Tested" values.

Duct leakage factors shown in Table 4.3 shall be used in calculations of delivery effectiveness.

Table 4.3 Duct Leakage Factors		
	Duct Leakage Diagnostic Test Performed using Section 4.3.8.2 Procedures	$a_s = a_r =$
Duct systems in homes built prior to 1999	Not tested	0.86
Duct systems in homes built after 1999	Not tested	0.89
<i>Duct systems in homes of all ages, — System with refrigerant based cooling, tested after house and HVAC system completion</i>	(Q_{25}) Total leakage is less than $0.06 Q_{ecool}$	0.96
<i>Duct systems in homes of all ages, — System without refrigerant based cooling, tested after house and HVAC system completion</i>	(Q_{25}) Total leakage is less than $0.06 Q_{eheat}$	0.96
Duct systems with refrigerant based cooling, in homes built after 1999,	(Q_{25}) Total leakage is less than $0.06 Q_{ecool}$	0.96

System tested with air handler installed, but prior to installation of the interior finishing wall	and final duct integrity verified	
Duct systems without refrigerant based cooling, in homes built after 1999, System tested with air handler installed, but prior to installation of the interior finishing wall	(Q_{25}) Total leakage is less than $0.06 Q_{\text{eheat}}$ and final duct integrity verified	0.96
Duct systems with refrigerant based cooling, in homes built after 1999, System tested without air handler installed, but prior to installation of the interior finishing wall	(Q_{25}) Total leakage is less than $0.04 Q_{\text{ecool}}$ and final duct integrity verified	0.96
Duct systems without refrigerant based cooling, in homes built after 1999, System tested without air handler installed, but prior to installation of the interior finishing wall	(Q_{25}) Total leakage is less than $0.04 Q_{\text{eheat}}$ and final duct integrity verified	0.96

4.3.8.2 Diagnostic Duct Leakage

Diagnostic duct leakage measurement is used to quantify total leakage for the calculation of air distribution efficiency. To obtain the improved duct efficiency for sealing the duct system, a diagnostic leakage test as described in section 4.3.8.2.1 or 4.3.8.2.2 must be performed. Houses built after 1/1/1999 shall not be allowed to claim duct leakage credit and diagnostic testing may not be done on any HVAC system that uses building cavities such as plenums or a platform return.

4.3.8.2.1 Diagnostic Duct Leakage from Fan Pressurization of Ducts

The total duct leakage shall be determined by pressurizing the ducts to 25 Pascals. The following procedure shall be used for the fan pressurization tests:

1. Seal all the supply and return registers, except for one return register or the system fan access.
2. Attach the fan flowmeter device to the duct system at the unsealed register or access door.
3. Install a static pressure probe at a supply.
4. Adjust the fan flowmeter to produce a 25 Pascal (0.1 in water) pressure difference between the supply duct and the outside or the building space with the entry door open to the outside.
5. Record the flow through the flowmeter ($Q_{\text{total},25}$) - this is the total duct leakage flow at 25 Pascals.

When the diagnostic leakage test is performed and the measured total duct leakage is less than 6% of the total fan flow, the duct leakage factor shall be 0.96 as shown in Table 4.3.

4.3.8.2.2 Diagnostic Duct Leakage at Rough-in Construction Stage Using An Aerosol Sealant Closure System

Duct leakage in new construction may be determined by using diagnostic measurements at the rough-in building construction stage prior to installation of the interior finishing wall when using an aerosol sealant closure system. When using this measurement technique, additional verification (as described in section

~~4.3.8.2.2.3) of duct integrity shall be completed after the finishing wall has been installed. In addition, after the finishing wall is installed, spaces between the register boots and the wallboard shall be sealed. Cloth backed rubber adhesive duct tapes shall not be used to seal the space between the register boot and the wall board.~~

~~The duct leakage measurement at rough-in construction stage shall be performed using a fan pressurization device. The duct leakage shall be determined by pressurizing both the supply and return ducts to 25 Pa. The procedures in Sections 4.3.8.2.2.1 and 4.3.8.2.2.2 shall be used for measuring duct leakage before the interior finishing wall is installed.~~

~~4.3.8.2.2.1 For ducts with the air handling unit installed and connected:~~

~~For total leakage:~~

- ~~1. Verify that supply and return plenums and all the connectors, transition pieces and duct boots have been installed. If a platform is used as part of the air distribution system, it must contain a duct, and all return connectors and transition parts shall be installed and sealed. The platform, duct and connectors shall be included in the total leakage test.~~
- ~~2. Seal all the supply duct boots and return boxes except for one return duct box.~~
- ~~3. Attach the fan flowmeter device at the unsealed duct box.~~
- ~~4. Insert a static pressure probe at one of the sealed supply duct boots.~~
- ~~5. Adjust the fan flowmeter to maintain 25 Pa (0.1 in water) between the duct system and outside or the building space with the entry door open to the outside.~~
- ~~6. Record the air flow through the flowmeter ($Q_{\text{total},25}$) - This is the total duct leakage at 25 Pa at rough-in stage.~~
- ~~7. Divide the measured total leakage by the total fan flow calculated from equation 4.4 or 4.5.~~

~~If the total leakage is less than 6% of the total fan flow, the duct leakage factor shall be 0.96 as shown in Table 4.3.~~

~~4.3.8.2.2.2 For ducts with air handling unit not yet installed:~~

~~For total leakage:~~

- ~~1. Verify that all the connectors, transition pieces and duct boots have been installed. If a platform is used as part of the air distribution system, it must contain a duct, and all return connectors and transition parts shall be installed and sealed. The platform, duct and connectors shall be included in the total leakage test.~~
- ~~2. Use a duct connector to connect supply and/or return duct box to the fan flowmeter. Supply and return leaks may be tested separately. If there is only one return register, the supply and return leaks shall be tested at the same time.~~
- ~~3. Seal all the supply duct boots and/or return boxes except for one supply or return duct box.~~
- ~~4. Attach the fan flowmeter device at the unsealed duct box.~~
- ~~5. Insert a static pressure probe at one of the sealed supply duct boots.~~
- ~~6. Adjust the fan flowmeter to maintain 25 Pa (0.1 in water) between the building conditioned space and the duct system.~~
- ~~7. Record the air flow through the flowmeter ($Q_{\text{total},25}$) - This is the total duct leakage at 25 Pa.~~
- ~~8. Divide the measured total leakage by the total fan flow calculated from equation 4.4 or 4.5. If the total leakage is less than 4% of the total fan flow, the total duct leakage factor shall be 0.96 as shown in Table 4.3.~~

4.3.8.2.2.3 Post rough-in duct leakage verification

After installing the interior finishing wall and verifying that one of the above rough-in tests was completed, one of the following post rough-in verification tests shall be performed to ensure that there is no major leakage in the duct system.

4.3.8.2.2.3.1 Visual inspection

Remove at least one supply and one return register to verify that the spaces between the register boot and the interior finishing wall are properly sealed. In addition, if the house rough-in duct leakage test was conducted without an air handler installed, inspect the connection points between the air handler and the supply and return plenums to verify that the connection points are properly sealed. All joints shall be inspected to ensure that no cloth backed rubber adhesive duct tape is used.

4.3.8.2.2.3.2 Pressure pan test

With register dampers fully open, the house is pressurized to 25 pascals by a blower door, (If two registers are within 5 feet of each other and are connected to the same duct run, one register shall be sealed off before the pressure pan test is performed). the pressure difference across each register shall not exceed 1.5 Pa.

4.3.8.2.2.3.3 House Pressure Test

The pressure difference between the building conditioned space and a vented attic shall be measured to determine whether the house pressure is changed appreciably by the operation of the air handler. To perform this test, the pressure difference ($P_{\text{house}} - P_{\text{out}}$) between the building conditioned space and a vented attic (or outside if impossible to access the attic), shall be measured four times:

1. with the fan off (ΔP_{off1})
2. with the fan on (ΔP_{on})
3. with the fan on and the return grille 80% blocked (ΔP_{RB}). Block 80% on all return grilles if the house has two or more returns.
4. with the fan off (ΔP_{off2})

For each of these measurements, the five-second average pressure shall be measured 10 times and these 10 measurements shall be averaged.

For the house to pass this test, the following conditions must be true:

1. $\Delta P_{\text{on}} - (\Delta P_{\text{off2}} + \Delta P_{\text{off1}}) / 2$ must be between +0.8 Pa and -0.8 Pa and
2. $\Delta P_{\text{RB}} - \Delta P_{\text{on}}$ must be less than 0.8 Pa.

In addition, the absolute value of $(\Delta P_{\text{off2}} - \Delta P_{\text{off1}})$ must be less than 0.25 Pa, or else the test must be repeated. If the repeated test does not meet the above specified values, visual inspection or the pressure pan test or the fan pressurization test must be used. If these tests fail, the duct system needs to be properly sealed and re-verified by a fan pressurization test.

4.4 Delivery Effectiveness (DE) Calculations

Seasonal delivery effectiveness shall be calculated using the seasonal design temperatures from Tables 4.2.

4.4.1 Calculation of Duct Zone Temperatures

The temperatures of the duct zones outside the conditioned space are determined in Section 4.3.5 for seasonal conditions for both heating and cooling. If the ducts are not all in the same location, the duct ambient temperature for use in the delivery effectiveness and distribution system efficiency calculations shall be determined using an area weighted average of the duct zone temperatures:

$$T_{amb,s} = \frac{(A_{s,attic} + 0.001)T_{attic} + A_{s,crawl}T_{crawl} + A_{s,base}T_{base}}{A_{s,out} + 0.001} \quad (4.7)$$

$$T_{amb,r} = \frac{A_{r,attic}T_{attic} + A_{r,crawl}T_{crawl} + A_{r,base}T_{base}}{A_{r,out}} \quad (4.8)$$

The return ambient temperature, $T_{amb,r}$, shall be limited as follows:

For heating, the maximum $T_{amb,r}$ is $T_{in,heat}$. For cooling, the minimum $T_{amb,r}$ is $T_{in,cool}$.

$$T_{amb,r} = \frac{T_{design} - 16^{\circ}F + \frac{\sum_{i=\text{duct location}}^{all\ return\ duct\ locations} A_i T_i}{outside\ conditioned\ space}}{2} \quad (4.20b)$$

4.4.2 Seasonal Delivery Effectiveness (DE)

The supply and return conduction fractions, B_s and B_r , shall be calculated as follows:

$$B_s = \exp\left(\frac{-A_{s,out}}{1.08 Q_e R_s}\right) \quad (4.9)$$

$$B_r = \exp\left(\frac{-A_{r,out}}{1.08 Q_e R_r}\right) \quad (4.10)$$

The temperature difference across the heat exchanger in the following equation is used:

for heating:

$$\Delta T_e = 55 \quad (4.11)$$

for cooling:

$$\Delta T_e = -20 \quad (4.12)$$

The temperature difference between the building conditioned space and the ambient temperature surrounding the supply, ΔT_s , and return, ΔT_r , shall be calculated using the indoor and the duct ambient temperatures.

$$\Delta T_s = T_{in} - T_{amb,s} \quad (4.13)$$

$$\Delta T_r = T_{in} - T_{amb,r} \quad (4.14)$$

The seasonal delivery effectiveness for heating or cooling systems shall be calculated using:

$$DE_{seasonal} = a_s B_s - a_s B_s (1 - B_{dr}) \frac{\Delta T_r}{\Delta T_e} - a_s (1 - B_s) \frac{\Delta T_s}{\Delta T_e} \quad (4.15)$$

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4.5 Seasonal Distribution System Efficiency

Seasonal distribution system efficiency shall be calculated using delivery effectiveness, equipment, load, and recovery factors calculated for seasonal conditions.

4.5.1 Equipment Efficiency Factor (F_{equip})

Equipment efficiency factor accounts for interactions between the duct system and the operation of the heating or cooling equipment. If the duct size and layout are designed and installed according to ACCA manual D and if the fan flow measurement meets the design specifications, the efficiency factor for F_{equip} is 1. Otherwise F_{equip} shall be 0.925. For heating, F_{equip} is 1.

4.5.2 Thermal Regain (F_{regain})

The reduction in building load due to regain of duct losses shall be calculated using the thermal regain factor. The default thermal regain factors are provided in Table 4.4.

Table 4.4 Thermal Regain Factors

Supply Duct Location	Thermal Regain Factor [F_{regain}]
Attic	0.10
Crawlspace	0.12
Basement	0.30
Other	0.10

4.5.3 Recovery Factor (F_{recov})

The recovery factor, F_{recov} , is calculated based on the thermal regain factor, F_{regain} , and the duct losses without return leakage.

$$F_{\text{recov}} = 1 + F_{\text{regain}} \left(\frac{1 - a_s B_s + a_s B_s (1 - B_r) \frac{\Delta T_r}{\Delta T_e} + a_s (1 - B_s) \frac{\Delta T_s}{\Delta T_e}}{DE_{\text{seasonal}}} \right) \quad (4.16)$$

4.5.4 Seasonal Distribution System Efficiency

The seasonal distribution system efficiency shall be calculated using the seasonal delivery effectiveness from section 4.4.2, the equipment efficiency factor from section 4.5.1 and the thermal recovery factor from Section 4.5.3. Note that DE_{seasonal} , F_{equip} , F_{recov} must be calculated separately for cooling and heating conditions. Distribution system efficiency shall be determined using the following equation:

$$h_{\text{dist, seasonal}} = 0.98 DE_{\text{seasonal}} F_{\text{equip}} F_{\text{recov}} \quad (4.17)$$

where 0.98 accounts for the energy losses from heating and cooling the duct thermal mass.